EXECUTIVE SUMMARY

Background

This study was initiated to assess the industrial base capability to support DOD and DND alternative aviation fuel initiatives. The current nature of the alternative fuel industry required looking globally to ascertain capabilities and potential trends. The study identifies significant advances in the development, refinement, and actual application of several alternative fuel generation methods in countries other than the U.S. and Canada. Further, high levels of government planning, investment, and active support is present.

Scope and Approach

The study focused on industrial capability for alternative fuel technology worldwide. Specific emphasis was placed on military needs, and more specifically on military aircraft requirements. Particular attention was placed on the Coal to Liquid (CTL) and Gas to Liquid (GTL) processes. The approach used included review of existing reports, analyses, and technical documents, and contact with involved government agencies, commercial firms, industry associations, and recognized subject matter experts.

It is important to understand that the entire subject area of alternative energy is complex and extremely dynamic. This report is a snapshot in time. What is true today may well not be true tomorrow. Technological maturity, economic conditions, competing political interests, and changing environmental policies/concerns directly impact current and projected alternative fuel projects. Current U.S. activity is significantly constrained by existing legislation and the uncertain nature of pending legislation.

The Challenge/Problem – (See Section 1)

The United States is a significant consumer of energy. For one of the dominant energy sources, petroleum, the U.S. relies heavily on imports to meet our consumption demands – approximately 60% of our crude oil is imported. Many current petroleum suppliers are located in areas of the world where political conditions could easily and rapidly lead to instability with the potential to impact the cost or availability of their products. Given that existing U.S. petroleum reserves are limited (in terms of known reserves that have been/are currently providing supply), alternative fuels from non-traditional sources warrant serious consideration. Forecasted trends reinforce these concerns as global demand for additional energy, again particularly in petroleum, continues to rise with economic development in heavily populated countries.

Canada, on a per capita basis, is also a significant energy consumer. Both the U.S. and Canada, on a per capita basis, use approximately 1.8 times the energy as other developed nations. Canada is a net exporter of both crude oil and natural gas, exporting a third of their oil production and half of the natural gas they produce to their major trading partner, the U.S. Production of both is projected to increase. Development of domestic oil sands, which contain estimated oil reserves second only to Saudi Arabia and more than eight times U.S. oil reserves, has placed Canada in a leadership position with regard to energy policy.

Environmental concerns remain a major element in exploiting new domestic sources of energy. Readily available domestic sources have been taken off the table and significant constraints placed on all alternate fuel technologies. Environmental impact accommodation is now a key element in the decision process of any solution.

The Department of Defense (DOD) is a major consumer of energy, representing 97% of the total federal government's energy use. Within DOD, the Air Force is the major consumer of jet fuel, accounting for 64% of total DOD use. Both the DOD and the Air Force have established goals to reduce energy use and pursue alternative energy sources to reduce operating costs, reduce contribution to green house gas effects, and reduce dependence on foreign sources for energy supply.

DOD and Air Force energy use reduction and independence goals reflect a challenge to which synthetic fuels offer a solution. Overall energy strategies have been formulated to address energy needs for direct war fighting equipment (e.g., tanks, various land vehicles, aircraft, support equipment, etc.), and operations and support facilities (e.g., maintenance shops, hangars, personnel housing, etc.). Strategies focus on reduced consumption, more efficient use, and alternative fuel sources.

Sources of Energy – (See Section 2)

There are a variety of fossil and non-fossil sources of energy. The three major fossil fuels - petroleum, natural gas, and coal - provide the vast majority of current energy worldwide. Petroleum dominates the transportation sector, coal the generation of electricity, and natural gas the heating and the chemical industries with a growing role of as-needed gap filler in the transportation and electricity sectors.

The non-fossil category contains many interesting sources - nuclear, geothermal, hydropower, tidal power, ocean currents and temperatures, wind, solar, biomass, and hydrogen – all with important uses but, with the possible exception of biomass, no direct application to filling the aviation fuel need.

Fossil fuels as sources for alternative liquid fuels:

- Coal – can be converted to gaseous and liquid fuels. The U.S. has 27 % of the known world reserves and thus good potential for conversion to fuel. Coal however, does not present significant fuel opportunities for Canada given reserves of only approximately 1% of known world reserves. The fact that Canada obtains 62% of electricity from hydro generation, makes their coal reserves less of an issue.
- Natural gas – can be converted to liquid fuels. The U.S. has approximately 3.4% and Canada has 0.9% of the known world reserves.

Non-fossil fuels as sources for alternative liquid fuels:

- Bio-mass – provides extensive multiple sources, ranging from foods to waste organic materials, it can be used in several ways to produce energy, to include liquid fuels.

Petroleum, in addition to its traditional liquid form, can be obtained from "alternative sources". The significant domestic quantities available strongly suggest that they be considered.

- Petroleum – alternative sources
    - Tar sands (also called oil sands), are a combination of clay, sand, water and bitumen, a heavy black viscous oil. Tar sands can be mined and processed to extract the oil-rich bitumen, which is then refined into oil. The U.S. has an

estimated 12 to 16 billion barrels of tar sands oil reserves in Eastern Utah. Canada's development of the extensive oil sands deposits in Alberta has provided a significant domestic supply and export opportunity. Government-industry partnerships laid the foundation for a decade of technology breakthroughs and environmental improvements in the Canadian oil sands. This partnership provides an example of how working together to overcome the challenge of establishing alternative petroleum sources can contribute to economic growth and energy security.

  - Oil shale, which refers to any sedimentary rock that contains materials called kerogen, is another source. Oil shale must be heated in order to extract the oil. The U.S. government estimates a total of 1.8 trillion barrels of shale oil exist in the Colorado, Utah and Wyoming region.

Alternative Fuel Technologies – (See Section 3 and Appendix A)

It is necessary to understand the level of technological maturity of the processes that can generate liquid fuels from the available energy sources.

- Coal – processes for converting coal to liquid (CTL) fuels have a long, proven track record. The processes were developed in Germany and then used extensively during World War II. The primary process, the Fischer-Tropsch Process (F-T), is named after the two German scientists who discovered and developed it. The Sasol Company, in South Africa, continued development, refinement and commercial use of the process starting in the mid 1950s and continues development today. The F-T process is an indirect conversion process, which starts with synthetic gas produced from coal. The gas is then further processed into liquids and further refined. Coal can also be converted to liquid fuels using a direct liquefaction process. Again the process was developed in Germany and used extensively during World War II. The most-used process results in hydrogenation of the coal. Developed in 1913 by Fredrick Bergius and bearing his name, the process is just beginning to come back into commercial use today. Efficient, environmentally friendly implementation continues to be a challenge.

- Natural gas – can be converted to liquid fuels (GTL) using several proven processes. One is the Fischer-Tropsch process, being used by Sasol. Another, developed by Exxon-Mobil, is often referred to as the Mobil Process. Yet another player is Statoil of Norway. Shell, Exxon, and two smaller companies in the U.S., Syntroleum and Rentech, are also active players in continued development and demonstration of gas to liquid processes. All these sources claim to have viable, scalable processes. Sasol and Shell currently operate large scale commercial operations and have more under construction. Advantages in efficiency and emissions have made GTL the current synthetic fuel choice.

- Bio-mass – an energy source with direct application to generation of liquid fuels. Bio-mass can be used to generate ethanol, which can be converted to methanol, which in turn can be converted to gasoline by the proven Exxon-Mobile process. An ethanol production industry has emerged, although a marginal energy balance has made it vulnerable to low cost petroleum. Twenty percent of ethanol plants have closed during the past two year cycle of low cost petroleum. The procedure to extract and process plant oils from crops such as camelina and jatropha to produce various fuels has been demonstrated. Use of algae to generate lipids, a form of oil, has also been demonstrated.

Current cost and low yield pose challenges to being commercially viable. There are many ongoing efforts at a variety of levels in both the private and public sectors to refine bio-mass conversion processes so they can be applied economically at the commercial level. While much progress yet remains to be made, there is a direct connection to liquid fuels.

Petroleum is discussed to highlight the processes associated with the two alternative petroleum sources, oil sands and shale oil.

Petroleum alternative sources:

- Tar sands extraction processes are well established and continue to improve in commercial operations in Canada.
- Shale oil extraction is a less mature process and requires further development before it can be claimed as a viable, economical source.

Technology Deployment – (See Section 4)

Processes to produce to liquid fuels range from proven, mature, and commercially executed to just beyond the experimental stage. These conditions, combined with the price and availability of oil at any given time, have directly impacted the level and pace at which industry has invested in commercial applications.

- Coal
    - Coal to Liquid Indirect F-T (CTL-F-T) is an established, proven and on-going commercial industry located in South Africa. But, the first plant compatible with current regulatory requirements has yet to be built in the U.S. China is currently in the process of planning several CTL-F-T plants. While there have been several initiatives aimed at establishing this capability in the U.S., to date none has materialized. The generation of significant amounts of CO_2 is a major issue.
    - Coal to Liquid – Direct conversion is known as the Bergius process. This process was used in Germany during World War II, and is a proven method. While it is an established and proven process, output quality has been considered low, and it has not been in commercial use anywhere in the world until the December 2008 opening of a plant in China.
- Natural gas
    - Gas to Liquid (GTL) is an established, proven and ongoing commercial industry located mainly in South Africa. Either the indirect F-T process or a direct conversion process developed by Mobil can be used. Shell oil produces diesel from natural gas in a factory in Bintulu, Malaysia. On February 1, 2008, an Airbus A380 was the first commercial airliner to fly with GTL-based fuel. Sasol in South Africa has been increasing its use of natural gas as a feedstock for its F-T process. A major GTL plant opened in 2007 and two more are currently under construction in Qatar and Nigeria, where natural gas has previously been flared or otherwise disposed of as useless.

- Bio-mass
  - One current form of biofuel is ethanol. Ethanol production has existed for some time. In the U.S., the focus has been on corn grain feedstock, producing ethanol for use as a blending agent with existing petroleum-based fuels, or as a stand alone fuel. Ethanol presents significant energy balance and land use challenges. Strong interest led to legislative mandates being established at the federal level for pursuit of renewable bio-based fuels, particularly ethanol. Targets for production levels of biofuel projected out to the year 2022 have been established. Financial incentives have been offered to motivate producers to enter the market.
  - Aggressive efforts continue to develop other bio-mass sources, to include cellulosic materials and algae. While several successes have been claimed in the laboratory or with small scale pilots, none has reached a maturity level for large scale commercial application. Bio-mass combined with coal as feedstock to the F-T process aids in reducing the CO_2 footprint.
- Petroleum – alternative recovery
  - Tar sands - an established, ongoing commercial sector for recovery and production, primarily located in the province of Alberta, Canada. The current process consists of surface mining of the tar sands for further processing into crude oil. Second generation projects are currently underway using in situ recovery from underground formations. A majority of the high quality crude produced is exported to the U.S. Significant environmental issues related to water and natural gas usage and water contamination, are being addressed by emerging, new technologies.
  - Shale oil – the oil content called kerogen can be extracted from oil shale by the processing of retorting, or heating of the oil shale. Retorting can be done on the surface or using an in situ method, where in the oil shale is retorted in place by heating. Interest and investment in extracting petroleum from oil shale has risen and fallen with the price of conventional crude. Significant technical challenges and environmental issues have prevented any significant development of large scale, commercially viable facilities.

Building the Business Case – (See Section 5)

The viability of any alternative fuel enterprise will require a rigorous analysis of factors associated with both energy policy and energy markets. Energy policy includes four interrelated factors that can result in a changing legislative and regulatory environment:

- Political factor – government at federal and state levels is undertaking aggressive efforts to reduce greenhouse gas (GHG) emissions and develop renewable fuels. The Energy Independence and Security Act (EISA) of 2007 sets reduction goals, identifies proposed funding levels, and calls out alternative fuel production levels. It should be noted that if past history is an indicator, initiatives of this type have often failed to actually materialize, usually due to a fall in the price of crude oil. As oil prices fluctuate, governments may change incentives such as tax abatements and direct investment funding.

- Environmental factor – global warming and greenhouse gas contributions are driving establishment of legal emission levels and targets for reduction. Several of the proven alternative fuel production processes pose significant GHG emission control problems. Strategies such as the carbon cap-and-trade approach are being looked at as ways to motivate improvement and produce sources of funds. Businesses are working hard to show they are "green." Efforts are underway to continue assessing and refining carbon capture and sequestration methods.
- Life Cycle Greenhouse Gas Assessment – The concerns about climate change and emissions levels not only influence production methods, but also require their precise documentation. Life Cycle Assessment methods are used to trace the direct and indirect contributions of feed stock, land use, transportation modes, production facility construction, and fuel production processes. Results are used to compare various alternative fuels and to evaluate their comparison to traditional petroleum-based fuels.
- Economic factor – The possibility of a worldwide recession has all but shut off capital sources and led to high percentage equity requirements. Requirements to ensure that production processes can meet projected demand, and established emissions mandates are severely challenging businesses. Any solution must be a "drop in" fuel that is compatible with all the elements of the existing logistics system (e.g., transportation, distribution, and storage).
- Social factor – concerns over global warming, competition for energy, and recession are pressuring governments to act. These actions sometimes work at cross purposes when attempting to establish either incentives or barriers for alternative fuel production.

Assuming a potential supplier, despite the significant challenges, judges the policy environment as acceptable, the traditional elements of a business case must then be considered. The focus here is on the synthetic jet fuel product.

- Market analysis – in terms of government market, only the U.S. Air Force has established a goal for actual use of synthetic jet fuel. No other federal agency or department has expressed a firm intent. Commercially there are efforts underway, initial flight testing of commercial aircraft using synthetic fuels has been conducted, and a standard has been approved for F-T based synthetic fuels. However, standards have yet to be issued for other sources, such as bio-mass which would be a key factor in assuring consistent output from industry.
- Investment analysis – the choice of a synthetic fuel production process drives this element. Investment in a CTL-F-T production facility requires between three and six billion dollars and a lead time of up to ten years before production rates are reached. Increases in planned production output have a direct correlation to initial investment and start-up cycle times. There is also a limited industrial base providing equipment for these technologies. For example, extremely large reactor castings are only available at this time from overseas sources, mainly Japan. They have at least a two year lead time. A significant worldwide increase in nuclear power plant construction, which uses similar large pressure vessels, is increasing that lead time, although there is evidence of activity in the U.S. and elsewhere to develop the needed production capability. Mature process choices are CTL-F-T, GTL-F-T, or CTL Direct. In every case, up-front investment is

significant. In addition, GHG controls add additional cost and technology development challenges. Several experts, including the U.S. Department of Energy (DOE), have estimated that carbon control technologies will not be adequate to support large scale commercial operations for another decade. Issues with bio-mass continue to include costs tied to scale-up of the production processes.

- Return on Investment analysis – market demand and the price of conventional fuel will determine when (if at all) the investment will provide a return. Existing calculations are all tied to comparative costs associated with petroleum-based fuel, both for operating costs and end product cost. Analyses of various alternative fuels will typically state: "Production of this product is economically viable at XX$ per barrel of oil, and at a production rate of XX barrels per day." As the price of conventional fuel falls and ample supplies are available, the projected ROI becomes problematic.
- Risk analysis – risks include the size of the investment required, significant lead times for production facilities, the instability in the energy market, the technical challenges even when using a well established process, and the yet-to-be-proven management of GHG emissions. Consider that Sasol, which leads the world with its extensive experience and continued refinement of the CTL F-T and GTL F-T process, has experienced significant plant start-up problems with recent ventures.
- Alternatives assessment – Given the facts associated with the above elements, a business must decide if there are other places to pursue opportunities. In the case of alternative jet fuel, given the political forces, the unpredictable domestic market, the extremely high capital investment required, the length of time until a return is realized, and the risks associated with the market and technology uncertainty, it would not appear that many businesses would be motivated to enter this market.

U.S. Regulations, Laws, and Programs – (See Section 6)

There are several laws and federal level initiatives that, as part of their overall thrust, address alternative fuels. The primary ones and their applicable provisions are listed below.

- Clean Air Act – expanded in 1990 to include alternative fuels.
- President's Hydrogen Initiative – 2003 – hydrogen can be a key element in syngas production.
- Energy Policy Act – 2005
  - Set specific emission requirements for gasification projects.
  - Addressed carbon capture, set criteria for funding projects and provided Carbon Capture and Sequestration R&D funding at an average of $30M annually from 2006 through 2008.
- Energy Independence and Security Act (EISA) - 2007
  - Addresses Biofuels in Title II and Carbon Capture and Sequestration under Title VII.
  - Sets renewable fuel usage standards and identifies specific renewable fuels sources.

- Sets GHG reduction targets for renewable fuels.
- Provides $25M for DOE grants in support of Biofuel R&D and infrastructure.

Most recently, the U.S. House of Representatives passed the American Clean Energy and Security (ACES) Act, also known as the Waxman-Markey Act. The U.S. Senate passed the American Clean Energy Leadership Act. Both address several aspects of energy to include carbon cap-and-trade as a strategy to motivate actions to reduce GHGs.

The U.S. Department of Energy's 2009 budget in the specific area of Energy Efficiency and Renewable Energy, Biomass, and Bio-refinery Systems R&D, is $225M. Within DOE, the National Energy Technology Laboratory (NETL) supports the FutureGen Clean Coal project, which calls for construction of a first-of-its-kind coal-fueled near-zero-emissions power plant in Mattoon, Illinois. The project is a government-industry partnership. DOE's total expenditure is projected to be $1.073B. Of that, $1B is expected to come from the Recovery Act funds for carbon and storage research. The 20 member companies will contribute $20-$30M each over a four to six year period.

In DOD, the Defense Advanced Research Projects Agency (DARPA) has a Biofuels Program exploring energy alternatives and fuel efficiency in a bid to reduce the military's reliance on traditional fuel in DOD. Two commercial contractors and one university have been awarded a total of $13.1M to perform the research.

The Air Force Alternative Fuel Certification Office (AFCO), which was formed in 2007, is located at Wright-Patterson AFB. It was created to provide scientifically-based certification for synthetic fuel usage in Air Force aircraft. Efforts addressing alternative fuels were previously funded as part of the RDT&E for Aging Aircraft, but starting in 2009, the AFCO was separately funded in the amount of $28.5M for FY2009, with additional funds identified out through 2013.

Conclusions/Recommendations

This report's conclusions/recommendations are supported by findings from other analyses that have been conducted in the area of alternative fuels. Several of the more significant findings from those previous reports are presented here to enable full understanding of the status and potential future of the alternative fuels industrial base.

- RAND Technical Report, *Near-Term Feasibility of Alternative Jet Fuels*, was released in late 2009, after the research for this report was concluded. The joint MIT-RAND report was sponsored by the Federal Aviation Administration and draws on a 50-plus year history of research and analysis performed by MIT and RAND on alternative fuel resources for aviation and the effects of fuel on operations. The document covers background, potential fuel sources, related technologies and a look ahead. A key finding, stated in the summary is:

  "In the next decade, up to three alternative jet fuels may be available in commercial quantities. The alternative aviation fuels that are not derived from conventional petroleum that have the greatest potential over the next decade are as follows: (1) Jet A derived from Canadian oil sands and Venezuela's VHOs; (2) FT jet fuel produced from coal, a combination of coal and biomass, or natural gas; and (3) HRJ produced by hydro processing renewable oils."

- The *Defense Science Board Task Force on DOD Energy Strategy*, February 2008, found that DOD faces two primary energy challenges:
    - Unnecessarily high and growing battlespace fuel demand that:
        - Compromises operational capability and mission success,
        - Requires an excessive support structure at the expense of operational forces,
        - Creates more risk for support operations than is necessary, and
        - Increases life-cycle operations and support costs.
    - Almost complete dependence by military installations on a fragile and vunerable commercial power grid and national infrastructure, that places critical military and Homeland Defense missions at an unacceptably high risk of extended disruption.
    - The Task Force recommended that DOD invest in basic research to develop new fuel technologies that are too risky for private investments and to partner with private sector fuel users to leverage efforts and share burdens. The Task Force also recommended the DOD work with commercial partners to conduct full "well-to-wheel" life cycle assessments of each synthetic fuel technology under consideration.
- *Producing Liquid Fuels from Coal: Prospects and Policy Issues*; RAND ; James T. Bartis, 2008; prepared for USAF and NETL
    - *"The firms most capable of overseeing the design, construction, and operation of CTL plants are the major petrochemical companies, which have the technical capabilities and the financial and management experience necessary for investing in multibillion dollar megaprojects. They are also best suited to exploit the learning that would accompany early production experience. Yet none has announced interest in building first-of-a-kind CTL plants in the United States."*
    - *"How can the federal government encourage the early participation of these and other capable companies in the CTL enterprise? The answer lies in the creation of incentive packages that cost-effectively transfer a portion of investment risks to the federal government."*
    - *"We found that a balanced package of a price floor, an investment incentive, and an income-sharing agreement is well suited to do this. The investment incentive, such as a tax credit, is a cost-effective way to raise the private, after-tax internal rate of return in any future. A price floor provides protection in futures in which oil prices are especially low. And income-sharing agreement compensates the government for its costs and risk assumption by providing payments to the government in futures in which oil prices turn out to be high. Because the most desirable form of a balanced package depends on expectations about project costs, the government should wait to finalize its design until it has the best information on project cost that is available without actually initiating the project."*

- *"Loan guarantees can strongly encourage private investment. However, they encourage investors to pursue early CTL production experience only by shifting real default risk from private lenders to the government. …."*

- *"In summary, for the United States, our analyses indicate that the economic constraints and time required to bring carbon capture and sequestration to commercial viability will limit the maximum rate of CTL industrial development. By 2020, the maximum production level would be about 500,000 bpd. Post-2020 capability buildup could be fairly rapid, with U.S.-based CTL production in the range of three million bpd by 2030." [Rand: Producing Liquid Fuels from Coal, 2008 (47)]*

- National Academy of Sciences, *Liquid Transportation Fuels from Coal and Biomass: Technological Status, Costs, and Environmental Impacts, 2009.*
  - *"Attaining….reasonable quantities of alternative fuel….will require permitting and construction of ten or hundreds of conversion plants and the associated fuel transport and delivery infrastructure. It will take more than a decade for these alternative fuels to penetrate the U.S. market. In addition, investments in alternative fuels have to be protected against crude-oil price fluctuations."*
  - *"Integrated geologic CO_2 storage is key to producing liquid fuels from coal with greenhouse-gas life-cycle emissions comparable to those of gasoline. Commercial demonstrations of coal-to-liquid and coal-and-biomass-to-liquid fuel conversion technologies with integrated geologic CO_2 storage should proceed immediately if the goal is to deploy commercial plants by 2020. Detailed scenarios for market penetration of U.S. biofuels and coal-to-liquid fuels should be developed to clarify the hurdles and challenges facing full feedstock use and to establish the enduring policies required. Current government and industry programs should be evaluated to determine whether emerging biomass and coal conversion technologies can further reduce U.S. oil consumption and greenhouse-gas emissions over the next decade."*

- The MITRE Corporation, JASON Program Office, *Reducing DOD Fossil-Fuel Dependence*, 2006.
  - *"DOD is not a large enough customer to drive the fuel market or to drive future developments in alternative fuels. Accounting for less than 2% of U.S. consumption, DOD is likely to depend on the world-wide commercial sectors for its supply of alternative fuels."*
  - *"Liquid fuels from stranded natural gas provide the most economically and environmentally favorable alternatives to fuels from crude oil. Underground coal gasification (UCG) provides the next-best alternative from an economic perspective, but is only acceptable from an environmental perspective if GHG emissions (mostlyCO_2) from the fuel production processes are sequestered."*
  - *"Presently, liquid fuel from biomass processes do not compete economically with production of fuel from crude oil. Biofuels provide little, if any, net energy benefit. This is particularly the case, if the complete process is taken into account, and it is not economically competitive (without subsidies) with other uses of agricultural land, e.g., growing food. Current biomass-to-fuel methods of*

production present a significant environmental burden (GHG, soil depletion and erosion, waste water, etc).”

  - *“Fuel processes based on cellulosic ethanol, butanol, etc. could eventually provide a significant fraction of the fuel demands of the U.S., if they are proven economically viable and if associated environmental burdens are acceptable. Such processes do not exist at present, however, and neither they, nor other non-ethanol biofuels and biofuel processes can be assessed, either in terms of their economics or environmental ramifications, at this time.”*
  - *“Ethanol’s low energy density, high flammability, and transportation difficulties, relative to diesel and JP-8, for example, render it unsuitable as a DOD fuel.”*

NATIBO Alternative Fuels Working Group Conclusions/Recommendations

At present there is not an existing domestic industrial base or favorable business climate to support a rapid migration to use of alternative fuels sources for military aviation systems.

- Current business, environmental, economic, and social concerns present conditions that are less than favorable for a business decision to enter the alternative fuels market.
- Large project schedule slips remembered from nuclear generation plant construction and reinforced by current GTL construction experience combined with restrictive credit markets makes securing funding difficult.
- Perceived significant first article technical and integration risk is reinforced by problems experienced by the experts – Sasol Oryx, Chervon Escravos, and Shenhua Erdos.

The very pragmatic objectives that precipitated this industrial base assessment were driven by the need for source security and cost stability for required fuel. At the point the objectives were established and a process of attainment set in motion, it was assumed that a solution existed and was well on the way to commercial implementation. The technical and business community assumed that solution to be the production of synthetic fuel from coal through the Fischer-Tropsch (F-T) process.

A number of conditions have added new challenges to use of the Fischer-Tropsch process, adding technical challenges and complexity, impacting costs, and especially the anticipated implementation time-line. This situation has significantly altered future possibilities and made the recommendation of action paths significantly more complex. The following recommendation sets are based on these realities.

The recommendations below are focused on what the DOD and DND should do to actively engage with the industrial base for the purpose of enabling industry to meet the defined objective for jet fuel (both traditional and synthetic), both in terms of source and quantities. The recommendations are concentrated in four (4) focus areas that hold the greatest potential for benefit. The four focus areas are Planning, Technology Investment/Sharing, Collaboration, and Fuels Certification.

Recommendation 1 - Planning

DOD and DND should put plans in place that address:

- The course of action in the event of contingencies ranging from loss of supply, to a significant price increase which has catastrophic budget impact. Plans should consider various options, such as:
    - Expansion of traditional petroleum fuel sources, and equally important, additional domestic refining capacity which is currently a bottleneck. Many experts believe this would also put pressure on the global market as reduced demand has in the past two years.
    - Given current market conditions, the best role for DOD and DND is not major investment, but targeted investment in focused technologies (see technology investment/sharing below).
    - Processes involved in the application of Title 1 authorities and allocation of domestic production to national security requirements.
- Establish sustained approaches to address long term non-contingency driven energy usage and procurement, such as:
    - Continued interaction with industry (both energy producers and commercial customers) and environmental associations to maintain awareness of policy and market issues.
    - Identification and adoption of best practices in multiple areas related to energy usage, procurement, storage, and distribution.
    - Expansion of certification programs to non-aviation segments of the military enterprise.

Recommendation 2 – Technology Investment/Sharing

In conjunction with recommendation 1, implement a joint DOD/DND program that:

- Directly aides in and accelerates the further development, refinement, and expansion of existing small scale domestic F-T production processes, such as exist with Synthroleum and Renteck. Synthroleum was a domestic source for synthetic fuel for the initial Air Force buy in support of the Alternative Fuel Certification effort. In addition, the program should identify similar sources in Canada.
- Actively supports research to mature technologies that accelerate development of tar-sands recovery from the estimated two trillion barrel reserve located in the Green River Formation in Colorado, Wyoming, and Utah. Collaborate with Canada for technology and data sharing based on their well established tar-sands commercial experience.
    - The potentially huge quantities of fuel contained in tar sands and oil shale suggest that these sources not be summarily dismissed because of past inabilities to cope with production challenges. The NATIBO Alternative Fuels Working Group provides a direct technology/information sharing source, for the benefit of diligent, protracted problem solving.

- Evaluates the use of Title III or CRADA initiatives, and any Canadian equivalent, to demonstrate emerging processes that have operational potential as small-scale or mobile facilities.
    - Most current F-T plant designs are based on yet-to-be-validated conceptual models. The risk associated with launching a large-scale project with unproven designs and the extreme capital costs have been a major barrier to development. A necessary initial set of validation data and experience needs to be obtained at a reasonable cost and risk even if a compromise of scale efficiency is required. There are a small select number of programs that would be good candidate projects. Additionally, concepts have developed that value a small mobile fuel production capability.
    - Support an appropriate effort to achieve process maturity and scale-up, such as an advanced concept development program, a CRADA, or cost share/incentive. Incentives such as a guaranteed joint fuel quantity purchase over an extended period of time should be evaluated.

Recommendation 3 – Collaboration

Continued collaboration is necessary as both military requirements and the energy industry continue to rapidly change. Through formal agreements establish a government-to-government forum specifically focused on transition technologies in the area of energy processing and production. NETL could coordinate U.S. effort through an MOU between DOD and DOE. The forum would include Canadian fuels related programs under the National Research Council and associated laboratories, and U.S. DOE and DOD laboratories. Both DARPA and ARPA-E would participate. Areas of common interest should include:

- Address key areas such as carbon dioxide, water use, gasification processes, and process efficiencies. Support the demonstration of large-scale coal gasification and integrated carbon capture through the U.S DOE FutureGen and the Canadian Genesee-ASAP projects. The integration of multi-phase, continuous-flow balanced processes like coal gasification or F-T fuel production with the collection and disposition of CO_2 is considered a significant risk because of both the balancing challenge and the large quantities involved. Many experts have suggested that several full-scale demonstrations of this integration are a mandatory prerequisite to mature low-risk commercial implementation.
- Evaluate and document the characteristics and quality of fuel products from other coal-to-liquid fuel processes (like direct liquefaction, coal refining). The F-T process has traditionally been considered a preferred source of aviation fuel because of product quality and ease of product upgrading. However, an increasing number of developers claim that advancements in technologies have made other processes equivalent to the F-T process.
- Promote improvement of the Fischer-Tropsch process:
    - Continue F-T catalyst research.
    - Sponsor process modifications that increase efficiency and reduce water use.

    - Sponsor detailed investigation of hybrid facilities that import -rather than generate- process heat and hydrogen.
- Establish methods by which technical reports and related documents can be readily accessible to interested DOD and DND organizations.

Recommendation 4 – Fuel Certification

Continue fuel certification support and collaboration by DOD, DND, and a widening group of allies and international commercial airlines. Although much has been accomplished, many different emerging fuel candidates consider certification as a work in process.

A key business case element for synthetic fuel technology development and the construction of the required multi-billion dollar production facilities has always been an ensured market. Because the characteristics of aviation fuel are so tightly specified, the questions of equivalence and acceptability were significant issues. The USAF Alternative Fuel Certification effort answered these questions and defined the path forward:

- A process (MIL-HDBK-510) was established to evaluate candidate fuels and determine compatibility with aircraft engines and their fuel support systems.
- All USAF aircraft have been or are nearing certification for a 50/50 blend of FT fuels.
- Fuel, procedures, and support were provided to the Canadian DND to accomplish certification of select Canadian Forces aircraft.
- The resulting tech data formed the basis for the approval of ASTM- D7566 which set the standard for FT fuel use in commercial aircraft.
- The certification effort has now been expanded to assess and certify emerging bio-jet fuels.

Recommend the expanded use of alternative fuel certification standards and documentation such as the CAN/CGSB-3.23 (Grades Jet A and Jet A-1), CAN/CGSB-3.24 (Military Grades F-34 and F-44), U.S. MIL-DTL-83133, and MIL-DTL5624 to facilitate market growth. Once compliant to national product standards, alternative fuels could be sought and considered for procurement in support of domestic operations. For example, the established technical baseline has led thirteen commercial airlines to take initial steps toward a guaranteed purchase agreement with Rentech.